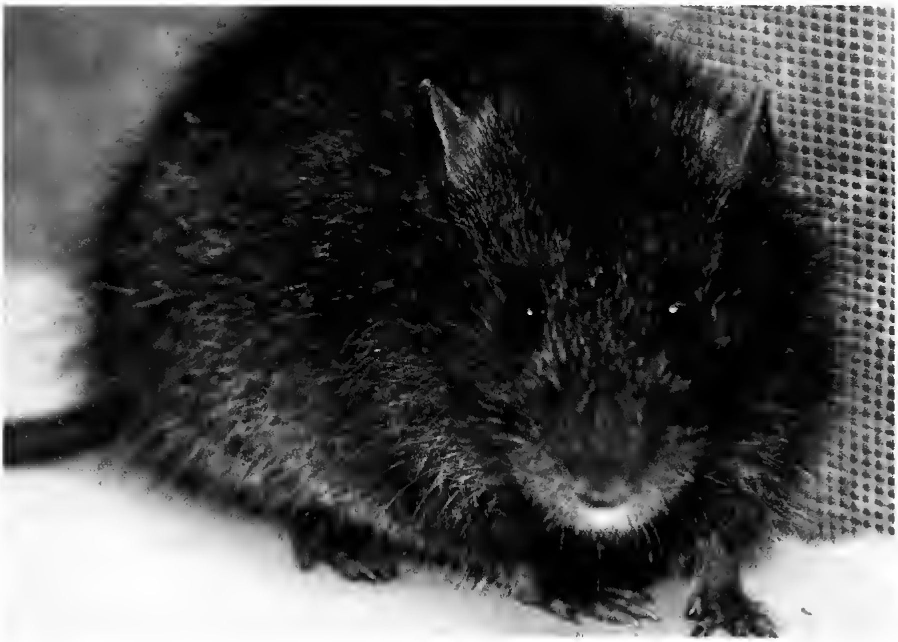
The Victorian Naturalist

Volume 129 (6) December 2012



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From the Editors

With the completion of another year of *The Victorian Naturalist*, it is opportune to reflect on this most recent volume as a whole. In the field of natural history publishing in this country, no other journal can claim the unbroken sequence of this one, so we derive no small pleasure in affirming both that fact and the wide-ranging nature of the subject matter on which we focus attention. In volume 129, we have published a total of 26 substantive papers. This sum includes 10 Research Reports that collectively look at many aspects of environmental studies, from vascular plants to bryophytes and mammals to marine species, and including invertebrates and vertebrates. A similar diversity is evident in the 10 Contributions published this year, as well as in the six Naturalist Notes.

The editors look forward to compiling volume 130, and to continuing the promotion of Australian natural history research in all its variety.

The Victorian Naturalist
is published six times per year by the

Field Naturalists Club of Victoria Inc
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Yearly Subscription Rates – The Field Naturalists Club of Victoria Inc

(As of October 2012)

Membership category		Institutional	
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The Victorian Naturalist

Volume 129 (6) 2012 December

Editors: Anne Morton, Gary Presland, Maria Gibson

Editorial Assistant: Virgil Hubregtse

ISSN 0042-5184

Front cover: Swamp Rat *Rattus lutreolus.* Photo by David Walker. See page 192.
Back cover: Eastern Grey Kangaroo *Macropus giganteus.* Photo by Anne Morton. See page 192.

Survival and recolonisation following wildfire at Moyston West, Western Victoria. 1. Mammals

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Abstract
Wildfire is a common occurrence in south-eastern Australia affecting fauna populations in various ways. Data were collected at a site near Moyston in western Victoria on three occasions before and five occasions after wildfire. Seventeen mammal species were recorded pre-wildfire whilst 23 species were recorded post-wildfire. The diversity of insectivorous bats was not affected by the wildfire, maybe because a number of mature River Red Gums *Eucalyptus camaldulensis* with numerous suitable roosting hollows survived the wildfire. Populations of Sugar Glider *Petaurus breviceps*, Common Brushtail Possum *Trichosurus vulpecula* and Common Ringtail Possum *Pseudocheirus peregrinus* also survived the fire in an area of mature River Red Gums. A small population of Swamp Rat *Rattus lutreolus* survived the fire and successfully recolonised regenerating habitat. Yellow-footed Antechinus *Antechinus flavipes* and Eastern Pygmy Possum *Cercartetus nanus* were recorded in regenerating Heathy Woodland after wildfire severely burnt this vegetation. The population of Black Wallaby *Wallabia bicolor* increased three years after wildfire as regenerating vegetation produced dense cover. Few studies provide pre-wildfire and post-wildfire data, especially on mammals at inland woodland sites. (*The Victorian Naturalist* **129** (6) 2012, 192-202).

Keywords: Wildfire, inland woodlands, insectivorous bats, marsupials, rodents

Introduction

Numerous wildfires have burnt large parts of south-eastern Australia since European settlement 200 years ago. The intensity of fire and condition of local environments produces a range of effects on landscapes and mammal populations (Wilson and Friend 1999). Several studies have been conducted into recolonisation by mammals following wildfire in south-eastern Australia, especially in coastal heathland (Newsome *et al.* 1975; Fox *et al.* 1985; Wilson and Moloney 1985; Catling 1986; Lunney *et al.* 1987; Lunney and O'Connell 1988; Catling *et al.* 2001; Recher *et al.* 2009). There are, however, few studies that provide both pre-fire and post-fire data, especially on the effects of wildfire on populations of mammals at inland woodland sites (Friend 1993; Sutherland and Dickman 1999).

In December 2005 and January 2006 a severe wildfire burnt 46% of the Grampians National Park and adjoining areas in western Victoria, especially around the Moyston district. Wuurak is a 150 ha property situated seven km west of Moyston in western Victoria (Lat 37° 18'S, Long 142° 41'E) approximately 210 km west of the Melbourne CBD. The owners operate a native plant nursery on-site that provides indigenous plants for revegetation projects in surrounding districts. Small scale sheep grazing is also conducted at the property. Wuurak is located on the plains east of Mt William, the highest point in the neighbouring Grampians National Park (Fig. 1). The terrain is mostly flat grazing country; however, an ancient sand-dune system covers a large proportion of the western and central parts of the property. Reservoir Creek, an ephemeral tributary of Mt William Creek, flows in a northerly direction along the eastern boundary.

Four Ecological Vegetation Classes (EVCs) are represented (DSE 2004). Heathy Woodland and Sand Forest (partly degraded) exist on the ancient sand-dune system; Damp Sands Herb-rich Woodland exists along Reservoir Creek; and Plains Grassy Woodland is present across the northern section of the property. Grazing was conducted along Reservoir Creek by previous owners and some introduced weed species exist in this part of the property. The current owners joined the Victorian Government's Land for Wildlife voluntary conservation scheme in 2002 and have since carried out several conservation initiatives including fencing off large areas along Reservoir Creek and revegetation

Fig 1. Wuurak Land for Wildlife property, with Mt William in background. Photo by Peter Homan.

of degraded areas. The Heathy Woodland section of Wuurak adjoins the eastern extremity of the Grampians National Park and, apart from this area of crown land, much of the indigenous vegetation in other neighbouring properties is degraded or fragmented to some extent. A study of the presence and relative abundance of vertebrate fauna commenced at Wuurak in October 2004 and the property was severely affected by wildfire in January 2006.

Methods

Several methods were used pre-wildfire and post-wildfire to detect the presence of mammals. These were cage trapping (Wiretainers Pty Ltd, Preston Victoria), Elliott trapping, type A (Elliott Scientific Equipment, Upwey, Victoria), harp trapping (Faunatech, Bairnsdale Victoria and Ecological Consulting Services, Newport, Victoria), pitfall trapping, remote surveillance cameras (Scoutguard, Models: SG550V and KG680V, China), spotlighting on foot and general observation. One pitfall line consisting of ten 20 L plastic buckets was established on a sand-dune in the area of Heathy Woodland. Buckets were 5 m apart and a 30 cm high aluminium flywire drift fence stretched for 60 m. Cage and Elliott traps were set in lines of 10 with 20 m between traps. Cage trapping was conducted pre-wildfire only; remote surveillance cameras were introduced as a replacement for cage traps post-wildfire. The number of cameras varied between four and six and were set approximately 25 m apart in small natural clearings where minimal disturbance to vegetation was necessary. Cameras were set facing in a southerly direction to avoid sun-glare. Harp trapping was restricted mainly to Damp Sands Herb-rich Woodland and Sand Forest due to a lack of suitable trapping sites in the other EVCs. Baits for traps and camera stations consisted of a mixture of smooth peanut butter, quick oats, golden syrup, sardines and vanilla essence. Common and scientific names and taxonomy follow Menkhorst (1995), except for House Cat *Felis catus* and European Hare *Lepus europeaus*, which follow Menkhorst and Knight (2011).

The study sites were visited on three occasions before wildfire (October 2004, November 2004 and March 2005) and on five occasions after wildfire (December 2008, April 2010, Decem-

Table 1. Survey methods and effort (trap-nights, camera-nights, spotlight hours) completed pre-wildfire and post-wildfire for each Ecological Vegetation Class (EVC). DSHRW = Damp Sands Herb-rich Woodland; PG Woodland = Plains Grassy Woodland; RSC = remote surveillance camera; S/H = spotlight hours.

		Survey Method					
EVC		**Elliott**	**Cage**	**Pitfall**	**Harp**	**RSC**	**S/H**
Heathy Woodland	Pre-fire	300		60			2
	Post-fire	340		80		10	2
DSHRW	Pre-fire	60	156		10		8
	Post-fire	150			15	22	14
PG Woodland	Pre-fire				2		
	Post-fire						
Sand Forest	Pre-fire						2
	Post-fire				8		1

ber 2010, March 2011 and April 2012). Overall, 1213 trap-nights were completed; 588 pre-wildfire and 625 post-wildfire (Table 1).

Results

Pre-wildfire

Seventeen species were recorded before wildfire: one monotreme, seven marsupial and nine eutherian (Table 2). Fourteen species were native and three were introduced. One Short-beaked Echidna *Tachyglossus aculeatus* was seen in Damp Sands Herb-rich Woodland. Diggings typical of those made by this species were also found in this EVC and Heathy Woodland. Yellow-footed Antechinus *Antechinus flavipes* was captured in Elliott traps overnight and during the day in Heathy Woodland and Damp Sands Herb-rich Woodland (Fig. 2). The species was also seen on two occasions during the day feeding high in the canopy of flowering Shining Peppermint *Eucalyptus willisii* in the Heathy Woodland area.

Sugar Glider *Petaurus breviceps* was seen during spotlighting in Heathy Woodland and in Sand Forest. Common Brushtail Possum *Trichosurus vulpecula* and Common Ringtail Possum *Pseudocheirus peregrinus* were seen during spotlighting in Damp Sands Herb-rich Woodland. Common Brushtail Possum was also recorded in Sand Forest. Small numbers of Black Wallaby *Wallabia bicolor* were recorded in Damp Sands Herb-rich Woodland and Heathy Woodland. Significant numbers of Red-necked Wallaby *Macropus rufogriseus* were recorded in Heathy Woodland, Plains Grassy Woodland and Sand Forest. Large numbers of Eastern Grey Kangaroos *Macropus giganteus* were seen in open grassy areas of the property. White-striped Freetail Bat *Tadarida australis* was heard in Damp Sands Herb-rich Woodland. Little Forest Bat *Vespadelus vulturnus*, Southern Forest Bat *Vespadelus regulus*, Large Forest Bat *Vespadelus darlingtoni* and Lesser Long-eared Bat *Nyctophilus geoffroyi* were recorded in Damp Sands Herb-rich Woodland. Swamp Rat *Rattus lutreolus* (front cover) was captured in Elliott and cage traps in Damp Sands Herb-rich Woodland. Burrows and runways of this species were found throughout this EVC. Two House Cats *Felis catus* were seen during spotlighting in Damp Sands Herb-rich Woodland.

Post-wildfire

Twenty-three species were recorded post-wildfire: one monotreme, eight marsupial and 14 eutherian (Table 2). Eighteen species were native and five were introduced. One Short-beaked Echidna was seen in Damp Sands Herb-rich Woodland during the first visit to the property post-wildfire in December 2008. Yellow-footed Antechinus was recorded in the Heathy Woodland area five years after wildfire and in Damp Sands Herb-rich Woodland and in Sand Forest six and a half years after wildfire. Common Brushtail Possum was recorded in Damp Sands Herb-rich Woodland three years after fire and in Heathy Woodland six and a half years after fire. Eastern Pygmy Possum *Cercartetus nanus* was captured in a pitfall trap four and a half years after wildfire (Fig. 3) and in an Elliott trap six and a half years after wildfire in Heathy Woodland. Sugar Glider was recorded in Damp Sands Herb-rich Woodland five years after wildfire and in Heathy Woodland and Sand Forest six and a half years post-wildfire. Common Ringtail Possum was seen

Table 2. List of mammals and numbers recorded pre-wildfire and post-wildfire for each Ecological Vegetation Class (EVC). DSHRW = Damp Sands Herb-rich Woodland; HW = Heathy Woodland; SF = Sand Forest; PGW = Plains Grassy Woodland; E = estimated number; * = introduced species; i = indirect evidence (digging, scats etc).

		Pre-wildfire			Post-wildfire				
Species	**EVC**	**10/04**	**11/04**	**3/05**	**12/08**	**4/10**	**12/10**	**3/11**	**4/12**
Short-beaked Echidna *Tachyglossus aculeatus*	DSHRW		1		1				i
	HW			i					
Yellow-footed Antechinus *Antechinus flavipes*	DSHRW			4					1
	HW			10			1		
	SF								1
Common Brushtail Possum *Trichosurus vulpecula*	DSHRW	1	14	10	7	6	7	6	5
	HW								1
	SF		2						
Eastern Pygmy Possum *Cercartetus nanus*	HW					1			1
Sugar Glider *Petaurus breviceps*	DSHRW						1		
	HW			1					1
	SF		1						1
Common Ringtail Possum *Pseudocheirus peregrinus*	DSHRW		1						2
Eastern Grey Kangaroo *Macropus giganteus*	PGW	20E	60E	100E	50E	50E	100E	150E	200E
Red-necked Wallaby *Macropus rufogriseus*	HW			5		2	1	1	4
	SF	5	15	10	5	2	2	5	5
	PGW		10	5	3				
Black Wallaby *Wallabia bicolor*	DSHRW		5		20E	7	3	3	2
	HW		2	1			1	3	1
White-striped Freetail Bat *Tadarida australis*	DSHRW		1	1	2	2	1	1	2
Gould's Wattled Bat *Chalinolobus gouldii*	DSHRW							3	1
Chocolate Wattled Bat *Chalinolobus morio*	DSHRW							6	
	SF						2	2	1
Large Forest Bat *Vespadelus darlingtoni*	DSHRW		1			1		1	2
	SF								1
Southern Forest Bat *Vespadelus regulus*	DSHRW		1	1				1	1
Little Forest Bat *Vespadelus vulturnus*	DSHRW		2	3		1		1	
	SF						1		1
Lesser Long-eared Bat *Nyctophilus geoffroyi*	DSHRW		7	1	4			11	11
	SF							3	2
Gould's Long-eared Bat *Nyctophilus gouldi*	DSHRW					1		2	3
House Mouse *Mus musculus* *	DSHRW			4		41			1
	HW			1		1	3	19	1
Swamp Rat *Rattus lutreolus*	DSHRW		1	2	i	1	i	i	i
Black Rat *Rattus rattus* *	DSHRW					1			1
Red Fox *Vulpes vulpes* *	PGW				2		1	1	1
House Cat *Felis catus* *	DSHRW		2						
European Rabbit *Oryctolagus cuniculus* *	DSHRW		1						
	PGW				1	1	1	5	7
European Hare *Lepus europeaus* *	PGW							1	1

Fig 2. Yellow-footed Antechinus *Antechinus flavipes*. Photo by Peter Homan.

during spotlighting in Damp Sands Herb-rich Woodland six and a half years post-wildfire.

Eastern Grey Kangaroo and Black Wallaby were recorded in increased numbers post-wildfire, whilst Red-necked Wallaby was recorded in reduced numbers post-wildfire. White-striped Freetail Bat and Lesser Long-eared Bat were recorded three years post-wildfire in Damp Sands Herb-rich Woodland. Little Forest Bat, Large Forest Bat and Gould's Long-eared Bat *Nyctophilus gouldi* (Fig. 4) were recorded in Damp Sands Herb-rich Woodland four and a half years post-wildfire. Chocolate Wattled Bat *Chalinolobus morio* was recorded in Sand Forest five years post-wildfire. Southern Forest Bat and Gould's Wattled Bat *Chalinolobus gouldii* were recorded five and a half years post-wildfire in Damp Sands Herb-rich Woodland. Burrows and runways typical of those made by Swamp Rat were found three years post-wildfire in a small unburnt area of Damp Sands Herb-rich Woodland. Swamp Rat and Black Rat *Rattus rattus* were photographed by remote surveillance camera in Damp Sands Herb-rich Woodland four and a half years after wildfire. Significant numbers of House Mice were captured in Damp Sands Herb-rich Woodland four and a half years post-wildfire and in Heathy Woodland five and a half years post-wildfire. Red Fox *Vulpes vulpes* was seen in Plains Grassy Woodland three years after fire. Numerous European Rabbits *Oryctolagus cuniculus* and smaller numbers of European Hares *Lepus europeaus* were seen in Plains Grassy Woodland six and a half years post-wildfire.

Discussion

Insectivorous bats make up a significant proportion of native mammal populations in many parts of south-eastern Australia, especially in fragmented landscapes in agricultural districts (Lumsden and Bennett 2000). Lumsden *et al.* (1995) suggested that bats are more tolerant of habitat fragmentation than other vertebrates and that several factors, including the ability to fly, colonial roosting habits and overlapping foraging areas, enable insectivorous bats to live successfully in farmland environments.

All insectivorous bats recorded in the Grampians and surrounding agricultural areas, except Common Bent-wing Bat *Miniopterus schreibersii*, use tree hollows as roosting sites (Menkhorst 1995; Churchill 2008). Studies in Tasmania and south-east New South Wales

Fig 3. Eastern Pygmy Possum *Cercartetus nanus*. Photo by Adam Merrick.

found that several species of forest bats favour roost sites in large, old trees with a diameter-at-breast-height of over 80 cm (Lunney *et al.* 1988; Taylor and Savva 1988). Lumsden *et al.* (2002) found that preferred roost sites for Gould's Wattled Bat were in dead spouts of living, large, old River Red Gums *Eucalyptus camaldulensis*. At Wuurak and on surrounding properties these kinds of hollows were present in large River Red Gums that survived the wildfire. Lumsden *et al.* (2002) radio-tracked Gould's Wattled Bats and Lesser Long-eared Bats in northern Victoria and found that individual bats foraged in farmland up to 12 km from roosting sites in forested areas. Lunney *et al.* (1985) recorded Chocolate Wattled Bats foraging 5 km from roosting sites located in exceptionally large trees. Taylor and Savva (1988) recorded a female Lesser Long-eared Bat travelling 4.8 km from roost site to foraging area.

Several variables influence data obtained by bat trapping, especially in open woodland habitats, where a high number of possible flight paths may exist. It is therefore not unusual for a chosen trap site to fail to capture any bats, and hence traps may be moved to new locations that are considered possible capture sites. Sixteen individual bats from four species were captured pre-wildfire (12 harp trap-nights), whilst 63 bats from seven species were captured post-wildfire (23 harp trap-nights). The increase in species and numbers may be due to a number of factors. More surveys were conducted post-wildfire and hence there was an increase in survey effort. Five years after wildfire at Wuurak, dense regrowth along the edges of previously wide tracks in Sand Forest formed new and improved sites for harp trapping. A new trap-site near Reservoir Creek in Damp Sands Herb-rich Woodland, used post-fire only, was particularly successful. The significant increase in vegetation post-wildfire especially along Reservoir Creek may have caused a greater abundance of insects, making the site more attractive as a foraging location for bats roosting throughout the local district.

The Yellow-footed Antechinus has a wide distribution across central Victoria where it occupies mostly heathy woodland and dry sclerophyll forest on the inland side of the Great Dividing Range (Kelly 2006; Menkhorst 1995). The species can be locally common at sites with large areas of high quality habitat (Menkhorst 1995; Myers and Dashper 1999; Homan 2005).

Fig 4. Gould's Long-eared Bat *Nyctophilus gouldi*. Photo by Maryrose Morgan.

The Yellow-footed Antechinus has also been recorded in degraded and fragmented areas and in remnant, linear habitats along roadsides (Loyn *et al.* 2002; van der Ree 2003; Marchesan and Carthew 2004; Carthew *et al.* 2009; NMIT unpubl. data). Studies in fragmented landscapes near Euroa, Victoria and near Penola, South Australia showed that the species was able to move long distances through suitable habitat, but also across open, cleared farmland (van der Ree 2003; Carthew *et al.* 2009). The Yellow-footed Antechinus usually nests in tree hollows or hollow, fallen logs (Menkhorst 1995; Kelly 2006); however, the species will use other nest sites when these are not available (Menkhorst and Knight 2011).

Large scale wildfires often leave some areas only lightly burnt or completely unburnt. The wildfire at Wuurak severely burnt the Heathy Woodland area and surrounding areas, especially similar habitat in the adjacent Grampians National Park. The area of Damp Sands Herb-rich Woodland where Yellow-footed Antechinus was recorded pre-wildfire and all of the Sand Forest were also severely impacted by the wildfire. In particular, large numbers of old-growth eucalypts with many hollows and fallen logs with hollows were destroyed by the fire. Yellow-footed Antechinus (one juvenile male) was recorded at Wuurak in Heathy Woodland in December 2010, five years after wildfire. This individual most likely entered the property from areas of nearby habitat that escaped the fire or that were only lightly burnt. Yellow-footed Antechinus was subsequently recorded in Damp Sands Herb-rich Woodland and Sand Forest six and a half years post-fire. The species could recolonise Wuurak only by moving through adjacent regenerating vegetation or across adjacent fragmented habitats and open grazing land.

The Eastern Pygmy Possum inhabits a wide range of vegetation communities within Victoria including Heathy Woodland (Menkhorst 1995). The species is a generalist omnivore, but feeds extensively on nectar and pollen especially from the inflorescences of several species of *Banksia* spp. (Turner 1984; Ward 1990). Huang *et al.* (1987) analysed the faeces of Eastern Pygmy Possums at a site near Nar Nar Goon, Vic-

toria, and found that pollen was a predominant item during the flowering of *Banksia spinulosa*. At Wuurak the species was not recorded pre-wildfire, but was recorded on two occasions post-wildfire in Heathy Woodland. Prior to the wildfire only a small number of mature specimens of Silver Banksia *Banksia marginata* were present; however, following wildfire large numbers of this plant germinated. The first record of Eastern Pygmy Possum, a juvenile female, occurred in April 2010, four and a half years post-wildfire, which coincided with a major flowering event for Silver Banksia. A second individual, an adult female, was captured in April 2012, which also coincided with prolific *Banksia* flowering.

The recording of Eastern Pygmy Possum post-wildfire at Wuurak was unexpected, especially considering the severe impact by wildfire on the Heathy Woodland and surrounding areas. It is unclear whether the species was present before fire, and was simply not detected despite a significant amount of survey effort, or whether it recolonised from the neighbouring section of the Grampians National Park. The species usually nests in hollows, which were mostly destroyed by the wildfire; however, Ward (1990) noted that the Eastern Pygmy Possum is very mobile and is able to use a wide range of nest sites.

Studies at other sites have recorded Eastern Pygmy Possum following wildfire. In the neighbouring Grampians National Park, Stevens (2008) conducted an extensive post-fire mammal trapping survey two and a half years after wildfire. Eastern Pygmy Possum (one individual only) was recorded from an isolated site that was severely impacted by wildfire. This site was 3 km from the nearest area of unburnt vegetation. In the eastern Otway Ranges in Victoria, one Eastern Pygmy Possum was recorded one year after a severe wildfire (Wilson and Moloney 1985). Wilson and Moloney (1985) concluded that animals can survive wildfire if sufficient refuges, such as unburnt pockets of vegetation, are available. At Ku-ring-gai Chase National Park in New South Wales, Eastern Pygmy Possum was recorded 13 months after wildfire, but no specimens were captured in nearby unburnt vegetation (Sutherland *et al.* 2004). At Nadgee Nature Reserve in south-east New South Wales the species was recorded 2 to 3 months after a major wildfire, but was not recorded from this site during three years of survey effort immediately prior to the fire (Sutherland *et al.* 2004). Sutherland *et al.* (2004) suggested that the Eastern Pygmy Possum is a mid-storey species and, with the loss of this part of the habitat after fire, the species is forced to move across the ground. The studies in these two reserves demonstrated that the failure to trap Eastern Pygmy Possum on the ground in unburnt forest does not necessarily indicate its absence (Sutherland *et al.* 2004).

Three arboreal marsupials, Common Brushtail Possum, Common Ringtail Possum and Sugar Glider, were recorded pre-wildfire and post-wildfire. All three species are nocturnal and use hollows in trees for shelter during the day (Menkhorst 1995). Studies at several inland sites have demonstrated that these species are able to survive in small patches and fragmented landscapes (Lunt 1988; Downes *et al.* 1997; van der Ree *et al.* 2003; Homan 2009). The severe wildfire at Wuurak destroyed virtually all old-growth eucalypts in the Heathy Woodland, Sand Forest and Damp Sands Herb-rich Woodland. Despite the severe impact of the fire an area of old-growth River Red Gums with many hollows survived the fire with their canopy intact in a section of Damp Sands Herb-rich Woodland and adjacent Plains Grassy Woodland, along the northern section of Reservoir Creek. With surrounding areas severely impacted by wildfire, this section of River Red Gums became an isolated patch. All three arboreal marsupial species were recorded for the first time post-wildfire in this patch. In the Grampians National Park, Stevens (2008) also recorded Common Brushtail Possum from small and large isolated patches that survived wildfire. Newsome *et al.* (1975) found that Common Brushtail Possum and Common Ringtail Possum survived wildfire in Nadgee Nature Reserve in wet areas where the tree canopy had not been destroyed.

The Swamp Rat is found over a wide area of southern Victoria, where it inhabits dense vegetation in wet heath, damp woodland and sedgefields (Menkhorst 1995). The species constructs extensive runways and burrow systems especially through areas of sedges and damp grasses (Menkhorst 1995). At Wuurak, Swamp

Rats were found before wildfire in dense sedge vegetation in Damp Sands Herb-rich Woodland along Reservoir Creek. As this vegetation regenerated at Wuurak, Swamp Rat successfully recolonised, within five and a half years, all areas where the species had been recorded pre-wildfire. When the property was visited three years after wildfire the only evidence of Swamp Rat was found in a small section of Damp Sands Herb-rich Woodland covering approximately 0.5 ha that had survived the fire. Despite considerable searching at this time no other evidence of the species could be found along other sections of Reservoir Creek. One and a half years later, runways and burrows were found along another section of Reservoir Creek approximately 200 m further downstream, and one Swamp Rat was photographed by remote surveillance camera at this location. Five and a half years after wildfire, fresh burrows and runways were found along all sections of Reservoir Creek.

Other studies have recorded Swamp Rat successfully recolonising regenerating vegetation following wildfire. At Nadgee Nature Reserve, Swamp Rat was the first native mammal species to recolonise regenerating heathland six years after wildfire (Catling 1986). During another study at this location Swamp Rat was recorded two years after intense wildfire as grassy ground vegetation developed and one year after another wildfire partially burnt the study site (Recher *et al.* 2009). However, Stevens (2008) did not record Swamp Rat from any survey sites in the Grampians that were impacted severely or mildly by wildfire.

Two introduced rodents, House Mouse and Black Rat, colonised parts of Wuurak following wildfire, especially areas of Damp Sands Herb-rich Woodland along Reservoir Creek. The House Mouse is seen as an early coloniser of disturbed sites (Menkhorst 1995). The species has been recorded in large numbers at numerous locations following wildfire (Newsome *et al.* 1975; Wilson and Moloney 1985; Catling 1986). Recher *et al.* (2009) found that House Mouse colonised burnt areas within two years of wildfire and persisted for three to four years before disappearing. Lunney *et al.* (1987) found that the species reached plague proportions two years after fire in an area that was intensely burnt. In the Grampians, Stevens (2008) recorded a rapid resurgence of House Mouse two years after wildfire, especially at isolated sites many kilometres from unburnt vegetation. At Wuurak House Mouse was recorded in low numbers pre-wildfire, but numbers increased dramatically post-wildfire. In an area of Damp Sands Herb-rich Woodland the capture rate for House Mouse was 33.3% four and a half years after wildfire severely impacted this site. Two years later the capture rate at this location had dropped to 1%. In Heathy Woodland House Mouse capture rate was 11% five and a half years post-fire, but decreased to 0.8% six and a half years post-fire. Low capture rates for House Mouse in April 2012, corresponded to recolonisation by Yellow-footed Antechinus of all parts of Wuurak. Menkhorst (1995) suggested that in the presence of Yellow-footed Antechinus, House Mouse may be largely restricted to areas less favourable to Antechinus.

The Black Rat is found in many parts of western Victoria, especially near human habitation and around farm buildings (Menkhorst 1995). The species becomes established in areas where disturbance such as fire has displaced native rats (Menkhorst 1995).The Black Rat was not recorded from indigenous vegetation at Wuurak pre-wildfire; however, the owners of the property reported encountering the species occasionally around sheds and other human-made structures. The species was detected by remote surveillance camera on two occasions in Damp Sands Herb-rich Woodland along Reservoir Creek four and a half years and six and a half years post-wildfire.

In recent years remote surveillance cameras have become a common survey method to determine the presence of terrestrial mammals (Nelson *et al.* 2009; De Bondi *et al.* 2010; Johnston *et al.* 2012). In many instances, where there is no need to handle animals, cameras have replaced cage traps. Setting large numbers of cage traps, especially in thick vegetation, is very labour-intensive. Prior to wildfire at Wuurak the vegetation in Damp Sands Herb-rich Woodland was quite open, providing fairly easy access. Following wildfire, however, prolific regrowth of Swamp Gum *Eucalyptus ovata* combined with numerous fallen trees produced almost impenetrable thickets over much of this

EVC. This change in conditions made it almost impossible to replicate survey methods used and effort completed pre-wildfire. Due to the change in habitat structure, and with the ability of cameras to detect the presence of all terrestrial mammals recorded pre-wildfire and any possible additional species, remote surveillance cameras were chosen as an efficient and less labour-intensive alternative to cage trapping post-wildfire.

The three large macropod species recorded pre-wildfire were all recorded three years post-wildfire and during subsequent visits to the property. The Black Wallaby (also known as Swamp Wallaby) is widely distributed across much of Victoria (Menkhorst 1995). In recent decades the range of the species has expanded into many parts of western Victoria where it was previously unknown (Bird 1992). The Black Wallaby is a generalist browser and is often most numerous in dense understorey, especially in riparian vegetation (Menkhorst 1995). At Wuurak, dense vegetation developed following wildfire in Damp Sands Herb-rich Woodland along Reservoir Creek. When this habitat was visited three years post-wildfire, the population of Black Wallaby was noticeably higher than pre-wildfire. Numerous Black Wallabies were seen and fresh scats typical of those produced by the species were common. In Mumbulla State Forest in New South Wales, Lunney and O'Connell (1988) found that the population of Black Wallaby increased within two years of wildfire as shrub cover increased. Other studies in revegetation sites and plantations showed high usage by Black Wallabies of dense vegetation aged from two to four years (Floyd 1980; Hill and Phinn 1993).

The Red-necked Wallaby and Eastern Grey Kangaroo are both grazers (Menkhorst 1995). Both species rest during the day amongst vegetation in woodlands and forests and emerge at dusk or after dark to graze on adjacent grasslands (Hill 1981; Johnson 1987). Several years post-wildfire significant rainfall occurred in the Moyston district producing prolific growth of grasses and ideal grazing conditions for large macropods. Six and a half years post-wildfire the population of Eastern Grey Kangaroo had increased significantly and was noticeably higher than pre-wildfire. However, the Red-necked Wallaby population had not returned to pre-wildfire levels. This may be due in part to competition with Eastern Grey Kangaroos or to predation on juvenile wallabies by the Red Fox. Juvenile Red-necked Wallabies that have recently vacated the pouch are left in dense vegetation whilst adults graze in nearby areas (Johnson 1987). Menkhorst (1995) stated that predation by Red Foxes at this stage may be high. The Red Fox was common at Wuurak post-wildfire and predation by this species on juvenile wallabies may have adversely affected recolonisation by the Red-necked Wallaby.

Acknowledgements

The study was conducted under the terms of research permit nos. 10002377, 10004149 and 10005276 issued by the Department of Sustainability and Environment and approval nos 0207 and 2509 of the Wildlife and Small Institutions Animal Ethics Committee of the Department of Primary Industry. Maryrose Morgan of Carlton and Adam Merrick of Wuurak provided field assistance. Many thanks to the Merrick family for the invitation to conduct vertebrate surveys on their wonderful property. Two anonymous referees improved the original manuscript.

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Received 28 June 2012; accepted 20 September 2012

Bryophytes of urban industrial streetscapes in Victoria, Australia

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Abstract

The bryophyte floristics of industrial/commercial streetscapes of urban Victoria and the importance of various substrata to species richness were explored. Species richness was low compared to healthy natural environments. Thirty mosses from 14 families, and six liverworts, each from different families, were identified. Most species occurred at fewer than 30% of sites, showing the patchy nature of their distribution. Only three species occurred at more than half the sites. Markedly higher species richness occurred on soil than on any other substratum. Epiphytes were extremely few. The low bryodiversity of streetscapes, the patchy nature of the bryophytes and the high number of colonists suggest that the streetscapes have not fulfilled their potential in providing connectivity between urban and non-urban areas. Colonists characteristically occur early in the successional sequence of disturbed areas but, as streetscapes are continually disturbed, colonists effectively are climax species for this habitat. Better management of streetscapes to provide more complex habitat is needed to enable colonisation of these areas by bryophyte species that are more representative of our ever-shrinking natural habitats. (*The Victorian Naturalist* **129** (6) 2012, 203-214).

Key words: Bryophytes, urban, streetscapes, substratum, connectivity

Introduction

Biodiversity conservation is a global concern and there is a growing recognition that urban environments can play an important role (Savard *et al.* 2000). Indeed, scientific research in urban ecology has become a global focus (Porter *et al.* 2001). Most studies have concentrated on areas with remnant native vegetation that have become surrounded by the urban matrix and set aside as public reserves or parks. But the urban environment consists of a wide range of 'green space'—everything in cities that has vegetation (Brennan and O'Connor 2008)—including the front and back yards of homes in residential areas, football ovals, golf courses, riparian strips and streetscapes, to name but a few. Streetscapes collectively make up a large component of the urban environment and have potential for mitigating some of the impacts of urbanisation on native biodiversity. Maximum potential can be achieved only with careful management that considers the ecology of streetscapes.

The term 'streetscape' as used in the context of this paper refers to exterior public spaces located between the vehicular carriageway and privately owned property or between the vehicular carriageway and public property not deemed part of the road infrastructure, e.g. library, law court, park. The exterior walls of any building or fence separating public from private land are included in the definition as they also provide habitat for plants. Streetscapes (Fig. 1) can consist of footpaths/walkways, walls of a fence or building, and sections of land ('nature strips') separating the footpath/walkway from the road or adjacent property. The nature strips may be found in any stage of development, from barren soil through to completely landscaped gardens. Currently, there are no studies published that have investigated the bryophyte populations of urban streetscapes within Australia. This paper examines bryophyte distribution of streetscapes in Victoria, Australia, but focuses on streetscapes where arsenic is known to be released into the atmosphere as it forms part of a larger study investigating the effects of arsenic on bryophytes. Elsewhere in the world, streetscapes have been included in larger studies (Giordano *et al.* 2004; Grdovic and Stevanovic 2006) that examined the bryophyte flora of cities, but such studies are comparatively few.

As our natural areas shrink due to increasing urbanisation, streetscapes *could* provide important habitat for flora and fauna as well as provide connectivity to remnant vegetation. Bryophytes are important components of natural habitats and are vital to ecosystem functioning. They are known to play various roles in:

Fig. 1. An urban industrial streetscape.

primary and secondary succession (Hosokawa and Kubota 1957; Dilks and Proctor 1974; Bewley 1979; Proctor 1981; Furness and Grime 1982; Hearnshaw and Proctor 1982; Longton 1984; During 1992; Longton 1992; Breuil-See, 1993; Gibson 2006); soil formation (Longton 1984; Sveinbjornsson and Oechel 1992); water retention of soil (Moore and Scott 1979; Jarman and Kantvilas 1995); prevention of soil erosion by wind or water (Rogers and Lange 1971, 1972; Eldridge and Tozer 1996, 1997; Gibson 2006); nutrient cycling (Longton 1984; Rodgers and Henriksson 1976); nitrogen fixation (Rodgers and Henriksson 1976); the food web (Gerson 1969, 1982); provision of shelter and protection for invertebrates (Gerson 1969, 1982; Longton 1984; Davidson *et al.* 1990; Richardson 1991; Milne *et al.* 2006); provision of nesting materials for birds or rodents (Gerson 1982; Longton 1984); and provision of oviposit sites for invertebrates (Gerson 1982). The ecological role of bryophytes does not stop within urban regions, yet this area of study largely has been ignored by science. To understand the ecological importance of bryophytes in urban regions, a knowledge of which species occur and where would be helpful. This, sadly, is lacking for Australia.

This paper describes bryophyte floristics of industrial streetscapes within Melbourne, Geelong and Ballarat. The aims of the study were to determine:

1. what bryophyte species occur on industrial/commercial streetscapes of urban Victoria, and which are most widespread;
2. what families and genera occur and which are best represented; and
3. which substratum is most important in terms of providing greatest species richness.

It is hypothesised that a major component of the bryoflora will be common and widespread species, particularly colonists and fugitives. Both have comparatively short life spans and are common in disturbed habitats. Colonists expend much energy on both sexual and asexual reproduction (During 1979); fugitives in sexual reproduction (During 1979). Many small, long-lived spores are characteristic of both life strategies. The Pottiaceae and Bryaceae are predicted to be the most common and widespread families. Both families include cosmopolitan species common to urban regions (Gerdol *et al.* 2002; Aceto *et al.* 2003) and harsh environments. Soil is hypothesised to have the highest species richness. Soil is a common substratum on streetscapes as are trees, but epiphytes often are few in highly urbanised regions (Bates *et al.* 2001).

Methods

Study sites

As the work presented in this paper formed part of a larger project investigating the interaction of urban bryophytes with airborne arsenic, sites were restricted to those where arsenic was known to be released into the atmosphere. These sites were obtained from Australia's National Pollutant Inventory (NPI) database published by the Department of Environment and Heritage (http://www.npi.gov.au). Most sites occurred in industrial zones although some were in commercial zones (e.g. VH Operations in Parkville). Each site comprised of the streetscape surrounding a business, be it industrial or commercial, which released arsenic into the atmosphere. Seventy sites were located within

the Melbourne Metropolitan Area and surrounding suburbs, 16 sites were located within the Geelong area while the remaining two sites were in the city of Ballarat (Fig. 2). Annual arsenic emissions at sites ranged from 0.0019 to 120 kg based on figures reported in the NPI database.

Study sites are temperate with strong seasonal variations in temperature. Mean minimum and maximum daily temperatures were respectively: summer 13.9°C and 25.3°C; autumn 10.8°C and 20.3°C; winter 6.5°C and 14.1°C; spring 9.5°C and 19.5°C (Australian Bureau of Meteorology [BOM] [http://www.bom.gov.au/climate]). Mean monthly rainfall for summer, autumn, winter and spring was 49.1, 47.8, 47.0 and 56.5 mm respectively.

Bryophytes were collected in each season of 2004 from all available substrata along the perimeter of each site, where possible. The types of substrata a species occurred on were noted. Substrata were placed into the following categories:

1. trees;
2. gravel: species collected actually grew on soil between the gravel but this type of substratum is very different from soil without gravel because of movement of the gravel, hence we have kept the two as distinct entities;
3. rocks, which formed part of the landscaping at sites;
4. asphalt;
5. cement; and
6. soil, either exposed or with grass.

Identification

Bryophyte samples were collected from each site and returned to the laboratory for identification. Extreme care was taken when removing bryophytes from their substratum. Only a representative portion of each species was collected, ensuring minimal disturbance so that the colony would continue to grow.

Samples were identified to species level where possible using an Olympus SZ-PT dissecting microscope and an Olympus BH-2 compound microscope. Terminology and nomenclature followed that of Streimann and Klazenga (2002) for mosses and McCarthy (2003) for liverworts.

Fig. 2. Study sites of the Melbourne and Geelong urbanised regions. Numbers indicate the number of streetscapes examined in each locality.

Representative samples of each bryophyte were compared to voucher specimens held in the National Herbarium (Melbourne) for verification of identifications. Samples were lodged in the Deakin University herbarium (Melbourne Campus).

Results

Thirty-six species were identified (Table 1). Thirty species from 14 families were mosses; the remaining six species were liverworts, all from different families (Table 1). The best represented moss families were the Bryaceae and Pottiaceae with five and nine species respectively (Table 1). These two families occurred most frequently, i.e. at over 80% of the study sites (Fig. 3). The Fissidentaceae were represented by three species while the Ditrichaceae and Leucobryaceae each were represented by two species. The other moss families were represented by only one species. Two liverwort species could not be identified beyond genus.

Three moss families occurred at more than half the sites (Fig. 3): Bryaceae at 71, Pottiaceae at 66 and Brachytheciaceae at 46. Two other families, the Ditrichaceae and Funariaceae, occurred at 20 or more sites, while another three families, Fissidentaceae, Plagiotheciaceae and Leucobryaceae, occurred at more than 10 sites. The remaining six families occurred at eight or fewer sites (Fig. 3). Three species, *Bryum dichotomum*, *Bryum argenteum* and *Brachythecium rutabulum*, occurred at more than 40 sites. Another five species occurred at more than 30 sites. All other mosses occurred at fewer sites, most at fewer than 30% of sites, showing the patchy nature of their distribution. The most frequently occurring liverwort was *Chiloscyphus semiteres* var. *semiteres* which occurred at only 13 sites (Fig. 3). Each remaining hepatophyte occurred at no more than six sites (Fig. 3).

Bryophytes colonised all of the substrata sampled (Table 2); however, the level of colonisation varied between and within the various study sites. The most commonly colonised surface was soil, with all bryophyte species collected having colonised this surface at least once (Table 2). This was understandable as soil was the most commonly occurring substratum (Fig. 4) and is normally used as a means of separating the road side edge from the pedestrian footpath. Only a very limited number of sites lacked soil as part of their streetscape. Nature strips were normally covered in a variety of grasses, with either one or more trees present. Nature strips varied, some were landscaped with something as little as a series of large rocks or boulders placed at random intervals while others were well maintained, planted gardens. Pedestrian footpaths most commonly were made from poured slabs of concrete or cement; however, in many areas with high foot traffic, asphalt was used.

More species colonised cement footpaths than asphalt (Table 2). Cement footpaths provided more areas for colonisation, primarily in the region between each of the poured slabs, and in cement cracks caused by either changes in temperature, or from changes in the soil topography under the footpath. The cement cracks trap soil thereby promoting bryophyte growth, provide protection from trampling, wind or other forms of erosion and, generally, stay moist for longer periods of time than the surrounding surface. The higher species diversity also may be attributed to the higher frequency of cement (47 sites) as a substratum for colonisation when compared to asphalt (13 sites) (Fig. 4). While gravel footpaths may help reduce soil erosion from wind and rain, the continuing movement of the gravel explains the lower numbers of species on this substratum as the movement would prevent many bryophytes from being able to colonise these areas (Table 2).

Epiphytes were the least common, being found at only one study site and consisting of only *Tortula papillosa*, which was found growing in the fissures produced by the bark of *Quercus alba* (Table 2). No other vascular plants had epiphytic bryophytes colonising them, even though vascular plants occurred at 55 of the study sites (Fig. 4). This, possibly, was because the species of vascular plants normally planted in Victorian urban areas do not usually host many bryophytes although, in natural habitats, bryophytes can be found at the base of trunks of these species, especially of older individuals. The majority of trees were either *Melaleuca* species or *Eucalyptus* species. Both genera consisted of species that shed their bark on an almost constant basis, making it difficult for bryophytes to establish permanent colonies.

Table 1. Mosses and liverworts (indicated by asterisks) of Melbourne, Geelong, and Ballarat streetscapes. Bryophytes are listed in order of the number of sites at which a family occurred.

Family	No. of sites where families occurred (n=88)	Species
Bryaceae	71	*Bryum argenteum* Hedw.
		Bryum dichotomum Hedw.
		Bryum pachytheca Müll.Hal.
		Rosulabryum billarderi (Schwägr.) J.R.Spence
		Rosulabryum capillare (Hedw.) J.R.Spence
Pottiaceae	66	*Barbula calycina* Schwägr.
		Barbula crinita Schultz
		Didymodon torquatus (Taylor) Catches.
		Leptodontium paradoxum I.G.Stone and G.A.M.Scott
		Tetrapterum cylindricum (Taylor) A.Jaeger
		Tortula muralis Hedw.
		Tortula papillosa Wilson
		Tortula truncata (Hedw.) Mitt.
		Triquetrella papillata (Hook.f. and Wilson) Broth.
Brachytheciaceae	46	*Brachythecium rutabulum* (Hedw.) Schimp.
Ditrichaceae	27	*Ceratodon purpureus* (Hedw.) Brid. subsp. *convolutus* (Reichardt) Burley
		Ditrichum difficile (Duby) M.Fleisch.
Funariaceae	20	*Funaria hygrometrica* Hedw.
Fissidentaceae	16	*Fissidens curvatus* var. *curvatus* Hornsch.
		Fissidens leptocladus Müll.Hal. ex Rodway
		Fissidens taylorii var. *taylorii* Müll.Hal
Leucobryaceae	14	*Campylopus clavatus* (R.Br.) Wilson
	15	*Campylopus introflexus* (Hedw.) Brid.
Plagiotheceae	14	*Acrocladium chlamydophyllum* (Hook.f. and Wilson) Müll.Hal. and Broth.
**Geocalycaceae*	13	*Chiloscyphus semiteres* (Lehm. and Lindenb.) Lehm. and Lindenb. var. *semiteres*
Hypnaceae	8	*Calliergonella cuspidata* (Hedw.) Loeske
Polytrichaceae	8	*Polytrichum juniperinum* Hedw.
**Ricciaceae*	8	*Riccia bifurca* Hoffm.
Thuidiaceae	7	*Thuidiopsis sparsa* (Hook.f. and Wilson) Broth.
Grimmiaceae	6	*Grimmia pulvinata* (Hedw.) Sm. var. *africana* (Hedw.) Hook.f. and Wilson
**Fossombroniaceae*	5	*Fossombronia* sp.
**Lunulariaceae*	3	*Lunalaria cruciata* (L.) Dumort.
Orthotrichaceae	3	*Macromitrium microstomum* (Hook. and Grev.) Schwägr.
Ptychomitriaceae	3	*Ptychomitrium australe* (Hampe) A.Jaeger
**Adelanthaceae*	2	*Jackiella curvata* E.A.Hodgs. and Allison
**Cephaloziaceae*	2	*Cephaloziella* sp.

Interestingly, *T. papillosa* was collected from only seven of the 88 sites (Fig. 3), yet it colonised the most substrata of any of the species sampled (Table 2). The most commonly occurring species normally colonised more than one substratum, with most of them colonising at least three, and up to four, substrata (Table 2).

Discussion

Bryophyte species richness of streetscapes was low compared to natural environments. For instance, Jarman and Kantvilas (1995) found 165 bryophytes within Cool Temperate Rainforest in Tasmania; Carrigan (2009) found 96 species on rocks in Victorian Rainforest streams; Dell and Jenkin (2006) noted 88 species within Blackwood forest from the Otway Ranges in Victoria; and Floyed and Gibson (2006) identified 32 species occurring on a single fern species, *Dicksonia antarctica* Labill., within Victorian Cool Temperate Rainforest. These areas are particularly wet and known for their high species richness and diversity. Drier areas are not so diverse. Steer (2005) found that Box-Ironbark forests and woodlands had a total of

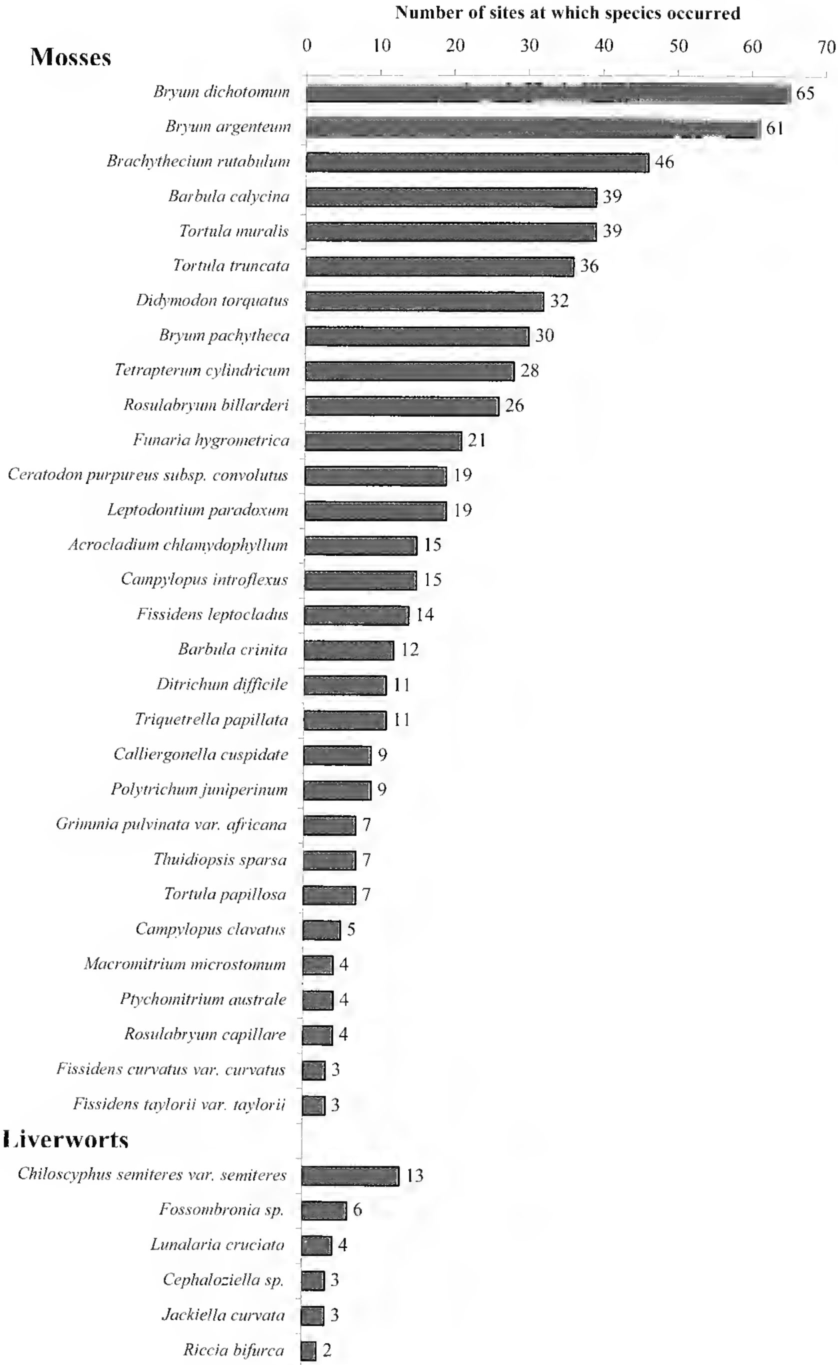

Fig. 3. Species frequencies of mosses and liverworts (n=88).

Table 2. Presence (+) of mosses and liverworts on various substrata. Liverworts are indicated by an asterisk.

Species			**Substrata**			
	Trees	Gravel	Asphalt	Rocks	Cement	Soil
Tortula papillosa	+		+	+	+	+
Bryum dichotomum		+	+		+	+
Campylopus introflexus		+	+	+		+
**Chiloscyphus semiteres* var. *semiteres*		+			+	+
Rosulabryum billarderi		+		+	+	+
Barbula calycina			+	+	+	+
Barbula crinita			+	+		+
Bryum argenteum			+	+	+	+
Bryum pachytheca			+		+	+
Tortula muralis			+	+	+	+
Brachythecium rutabulum				+	+	+
Didymodon torquatus				+	+	+
Grimmia pulvinata var. *africana*				+	+	+
Triquetrella papillata				+	+	+
Ceratodon purpureus subsp. *convolutus*				+		+
Funaria hygrometrica				+		+
Polytrichum juniperinum				+		+
Ptychomitrium australe				+		+
Calliergonella cuspidata					+	+
Fissidens leptocladus					+	+
Leptodontium paradoxum					+	+
Macromitrium microstomum					+	+
Tetrapterum cylindricum					+	+
Tortula truncata					+	+
Campylopus clavatus						+
**Cephaloziella* sp.						+
Ditrichum difficile						+
Fissidens curvatus var. *curvatus*						+
Fissidens taylorii var. *taylorii*						+
**Fossombronia* sp.						+
**Jackiella curvata*						+
**Lunularia cruciata*						+
**Riccia bifurca*						+
Rosulabryum capillare						+
Thuidiopsis sparsa						+
Total number of species	1	4	8	15	18	35
Number of sites with substratum	55	10	13	2	47	81

51 species. Revegetated woodland of agricultural land only had 24 species (Hattam 2007). These latter two studies were investigations of areas with much lower complexity than the earlier studies mentioned. Lower complexity of a habitat is generally considered to reduce species richness (Moser *et al.* 2002; Kostylev *et al.* 2005; Eriksson *et al.* 2006). The streetscapes investigated were of very low complexity so the paucity of bryophytes was not unexpected.

As predicted, the Bryaceae and Pottiaceae were well represented on the streetscapes. This has been reported in other studies (Gerdol *et al.* 2002; Aceto *et al.* 2003) and is not surprising as most species in these families were colonists. Indeed, half the species identified in the streetscapes were colonists: *Barbula calycina, B. crinita, Bryum pachytheca, B. argenteum, B. dichotomum, Campylopus clavatus, C. introflexus, Ceratodon purpureus* subsp. *convolutus, Didymodon torquatus, D. difficile, Grimmia pulvinata* var. *africana, Lunalaria cruciata, Polytrichum juniperinum, Rosulabryum billarderi, R. capillare, Tortula muralis, T. papillosa* and *T. papillata.* These species are characteristic of habitats that appear at unpredictable times and locations but which then last for several years (Moore and Scott 1979; Eldridge and Tozer 1996). They also tend to be cosmopolitan. If not cosmopolitan, they are widespread, occurring

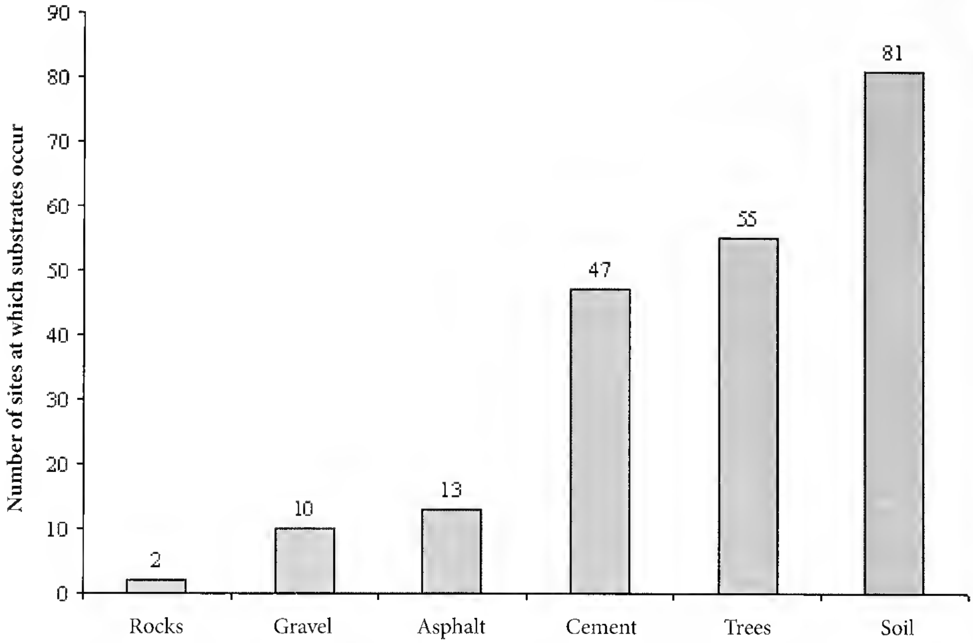

Fig. 4. Frequency of substrata at study sites (n=88).

in many different habitats. Such bryophytes expend a lot of energy on production of sexual and/or asexual propagules (During 1979) providing a resource for subsequent germination episodes either for the same area, if it remains disturbed, or for another disturbed area if propagules are distributed there. Streetscapes tend to be perpetually disturbed: when present, grass is mowed; there is high foot traffic; and trees or shrubs present are retained for their life span, thus there is no succession; road traffic causes high wind velocities close to the ground; and often soil is compacted so that flooding occurs with rain and desiccation in summer. Because of this, it is hardly surprising that so many species in streetscapes are colonists and found in harsh environments. *Funaria hygrometrica, P. juniperinum* and *Marchantia polymorpha,* for example, are primary colonisers after a fire (Bradbury 2006; Gibson 2006) and *Bryum argenteum, B dichotomum, Barbula calycina* and *Didymodon torquatus* commonly are found as part of soil crusts in arid and semi-arid habitats (Eldridge 1999).

Only one species, *Funaria hygrometrica,* had a fugitive life strategy, although some botanists class it as a colonist (http://www.anbg.gov.au). Fugitives characteristically occur in habitats that persist for short periods of time such as those occurring after fire (During 1979). Colonists occur in habitats that are disturbed but then remain for several years. All streetscapes examined have persisted for many years and the disturbances they experience are a 'natural' component of these ecosystems created by humans. In natural ecosystems, colonists may be pioneers in the successional story but, in the streetscapes examined, they also are the climax species.

Other bryophytes of streetscapes are more characteristic of a forest floor, for example, weft like species such as *Chiloscyphus semiteres* var. *semiteres* and *Brachythecium rutabulum* that form large open colonies in protected forests (Jarman and Kantvilas 2001; Downing *et al.* 2007); however, most of the streetscapes were not protected. *Brachythecium rutabulum* was the most common pleurocarpous species

found in this study and is known to be tolerant of summer frosts (Rutten and Santarius 1992), which would help improve its ability to survive in open spaces such as streetscapes. It is a cosmopolitan species and common in both urban and woodland regions worldwide e.g. King's Lynn, UK (Stevenson and Hill 2008), Belgrade, Serbia (Sabovljevic and Grdovic 2009), South Lancashire, UK (Ashton 2003), Western Ghats, India (Manju *et al.* 2009) and Legnica, Poland (Samecka-Cymerman *et al.* 2009).

It was interesting to note that trees were present at 55 of the 88 sites studied but that only one bryophyte species (*T. papillosa*) was epiphytic, even though bryophytes are well known to be epiphytic. The trees planted consisted principally of bark-shedding *Melaleuca* and *Eucalyptus* species, thus it is understandable that few bryophytes were found on them. In non-urban regions of Australia, epiphytes generally form a much greater proportion of the species in an area. For instance, Steer (2005) found that 36 of the 51 species of bryophyte identified from Box-Ironbark Forest could be epiphytic; Pharo and Beattie (2002) identified 26 epiphytic bryophytes for sclerophyll forest in New South Wales; Floyed and Gibson (2006) found 32 species on *Dicksonia antarctica* Labill. in Cool Temperate Rainforest; however, Kellar *et al.* (2006) found only four bryophytes on *Eucalyptus regnans* F.Muell., a bark shedding tree, but found that *Nothofagus cunninghamii* was colonised by 12 species of bryophytes. There can be many reasons why there were few urban epiphytic bryophytes at the study sites. Firstly, there usually is a greater diversity of host species for bryophytes to colonise in forests. In urban areas, planting of trees is determined by what is most appealing, available and/or practical in an area, with no, or little, thought given for any ecological roles that they may play within the ecosystem they are introduced into (Parsons *et al.* 2006; Williams *et al.* 2006). Also, there are usually very few tree species planted along any streetscape, often only one or two species.

Secondly, trees planted on nature strips do not have the protection of surrounding forest trees, thus these urban trees will be subjected to stronger wind forces, greater extremes in temperature and higher light regimes. This means that bryophytes probably will have longer periods of being in a dried state than their forest counterparts. Also, epiphytes would be subjected to greater dust deposition, which would include pollutants. These factors make urban habitats more difficult to colonise and, subsequently, to survive in.

Thirdly, unless the streetscapes are connected to or in proximity to a source of propagules, colonisation by more patchily distributed bryophytes would be infrequent or would not occur at all. As it is, very few of the bryophytes of streetscapes were common, with 25 species occurring in less than 20 of the 88 study sites, and *all* the species identified in the study are classed as common and widespread in Australia (Meagher and Fuhrer 2003)!

The fissuring that occurs in the bark of *Quercus alba* is the most probable reason for colonisation of this particular tree by bryophytes; however, only one bryophyte species was found. Ashton and McRae (1970), Pike *et al.* (1975), Kantvilas and Minchin (1989), Peck *et al.* (1995) and Martin and Novak (1999) suggest that fissuring provides new habitats for development and increased growth rates, explaining high epiphytic diversity in non-urban trees with fissured bark. Such diversity did not occur in this study, suggesting that factors other than substratum have influenced the colonisation of bryophytes on this host.

Colonisation of cement pavements always occurred within the crevices between each pair of slabs of cement, or where the cement had cracked and lifted, providing a sheltered area for colonisation. Colonies normally extended large distances along these crevices, in some instances taking up the complete length of the crevice from one side of the pavement to the other. The species occurring within these microhabitats were predominantly small acrocarpous species, which trapped the soil that collected around their lower regions, forming a thin soil bed. Pleurocarpous species were not as common as acrocarpous species but could occur in well-developed colonies.

The most heavily colonised substratum was soil. This was not surprising, as other studies, although non-urban, also showed soil to have high species diversity (Eldridge and Tozer 1996; Floyed 1999; Floyed and Gibson 2006; Milne *et al.* 2006). Soil provided a wide range

of microclimates, from exposed barren areas reminiscent of desert habitats, through to lush grass lawns, which offer greater protection from the elements and a greater level of water retention. Species composition appeared to be determined by what else grew on the soil. Pleurocarpus species of moss such as *Acrocladium chlamydophyllum* and *Brachythecium rutabulum* and the liverwort *Chiloscyphus semiteres* var. *semiteres* were found frequently growing amongst various grass species where conditions were quite wet, well shaded and provided a greater amount of protection from erosion by wind. Streetscapes where soil was shaded generally had a greater abundance of liverworts, but tended to be found only during the wetter periods of the year. While liverworts may well have been present in the soil propagule bank, they were found only after a rain incident or in areas with a continuous water supply adjacent to where they were found. Mosses, on the other hand, were found year-round under almost any types of conditions.

Concluding remarks

The low bryophyte diversity of streetscapes, the patchy nature of many species and the cosmopolitan distribution of many species has important conservation implications. Forests and other ecosystems are shrinking and becoming more fragmented as urban areas continue to spread. The streetscapes examined were simple habitats with very low complexity and were adjacent to industrial sites. Their low bryodiversity suggests an inability to support the species richness and diversity of more complex habitats such as forests and woodlands. The high number of colonists and cosmopolitan species indicates that urban expansion will result in the simplification of bryophyte communities, with rare species and later successional species likely to become locally extinct if provision is not made to set aside sufficient and appropriately managed parks for their survival. An optimistic hope is that streetscapes of non-industrial urban regions provide for a better bryodiversity, but this does not appear to be the case (pers. obs.).

Management of streetscapes has been suggested as a way of maintaining biodiversity and providing connectivity between forest fragments by White *et al.* (2005) who noted that streetscapes with similar vegetation types to those of closely associated parks of remnant forest had similar avian fauna, while streetscapes with exotic or limited flora had a decrease in both insectivorous and nectarivorous bird species. In terms of bryophytes, careful planning of streetscapes to provide more habitat complexity and flora indigenous to an area could provide for higher bryophyte diversity in urban areas and maintenance of species native to specific regions. Then streetscapes also would be more likely to provide a conduit for dissemination of bryophyte propagules from one region to another, allowing colonisation or recolonisation of an area by species other than those that are common and widespread.

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Received 12 July 2012; accepted 20 September 2012

Frozen in Time: Prehistoric Life in Antarctica

by Jeffrey D Stilwell and John A Long

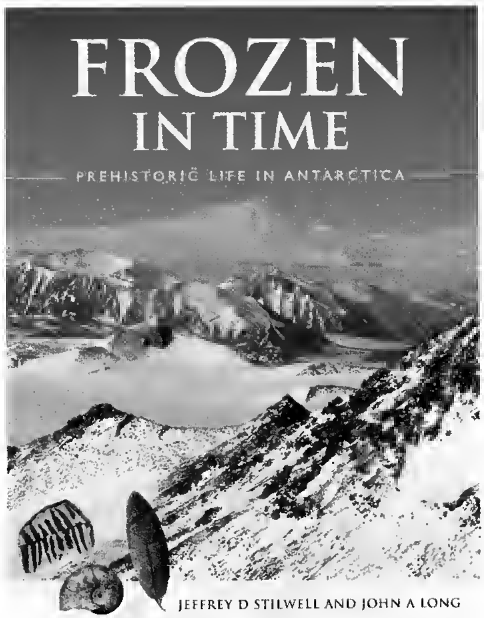
Publisher: *CSIRO Publishing, Collingwood, Victoria, 2011. 248 pages, hardback, colour illustrations. ISBN 9780643096356. RRP $69.95*

To try to tell the story of life on any of the Earth's continents in a single volume would be a daunting challenge. To illustrate the life-story of a continent, 98% of which is covered with ice up to 5 km thick, would seem impossible.

This is what Dr Jeffrey Stilwell and Professor John Long, the authors of *Frozen in Time: Prehistoric Life in Antarctica*, have set out to do and, in my opinion, they have succeeded brilliantly. This beautifully produced and profusely illustrated 238-page volume provides readers with almost everything they need to know about Antarctica's fascinating life history and, should they wish to explore farther, its 33 pages of further reading references provide an invaluable research guide.

We know little about Antarctic life during the first four billion years of Earth history (Precambrian Eon). Now, thanks to scientific discoveries by innumerable expeditions over the past century, we know that Antarctica has not always been ice-bound. For most of the time since the Cambrian Period, 540 million years ago, Antarctica has supported rich and diverse plant and animal life and has undergone major climatic changes.

By combining their different skills and expertise (Stilwell in ancient environments and



Long in the evolution of vertebrates) and their first-hand experience of different parts of Antarctica, the authors trace its history in a comprehensive, well-illustrated review based on its fossil record.

At different times Antarctica has formed part of several earlier super-continents, the latest of which, Gondwana, is now widely dispersed to form the present southern continents plus India. Antarctica provides crucial evidence linking all of these, including Australia.

Find out about Antarctica's rich Devonian fish faunas from Southern Victoria Land and their world-wide links; the Permo-Triassic amphibian and mammal-like reptile faunas with strong links to South Africa; the spectacular discovery of Jurassic dinosaur skeletons, recovered from high in the Trans-Antarctic mountains along the Beardmore Glacier; the discovery of fossil bird and mammal remains (including early marsupials) on Seymour Island, off the Antarctic Peninsula – and the fascinating stories behind these and many more.

Some of the descriptions are unavoidably a bit technical but don't be put off. The text is clearly written and is backed by a nine page scientific glossary. It is illustrated by a wealth of beautiful photographs, supplemented by artists' reconstructions, as well as stunning images of Antarctic landscapes.

In 1970–71 I had the good fortune to be invited to join a two-month-long New Zealand university expedition to Antarctica to search for Devonian fish fossils. It was an unforgettable experience and some of the finest specimens I discovered are featured in *Frozen in Tlime*.

I have always hoped that someone would write and illustrate the story of past life in Antarctica to let others share its fascinating history. Now Jeffrey Stilwell and John Long have done just that for the first time and we are in their debt.

I strongly recommend *Frozen in Time* and, if you can't buy it yourself, I suggest that you recommend it to your local public library or school library so everyone can enjoy it and share in the thrill of discovery on a frozen continent.

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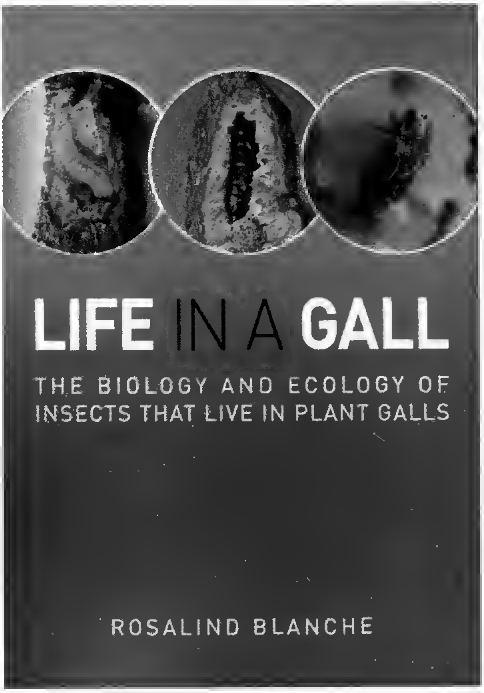
Life in a gall: The biology and ecology of insects that live in plant galls

by Rosalind Blanche

Publisher: *CSIRO Publishing, Collingwood, Victoria, 2012. 80 pages, paperback, colour illustrations. ISBN 9780643106437. RRP $29.95.*

The intricate relationships between insects and plants take many forms, from simple external herbivory to the subtle and highly specific associations that can result in insects living within plants as highly co-evolved foliage-miners or, as here, gall-formers. These varied taxa induce the plants to produce highly characteristic excrescences (galls) that serve as a domicile for the insect, leaving it unexposed to the outer world. Galls have for long intrigued biologists. The extensive arrays of cynipoid wasps forming galls on oak trees in the northern hemisphere, together with their numerous and equally specific associates (so that each gall can become the hub of a community of the primary gall-forming species, its parasitoids and inquilines) were studied, for example, by Alfred Kinsey long before his noteworthy studies of human sexuality.

Galls are very special structures, as Rosalind Blanche demonstrates in this excellent short introduction, and are induced by many kinds of insect as well as other animals and fungi. This book is both highly readable and scientifically informative, with its appeal enhanced by the numerous excellent colour photographs (many of them contributed by recognised experts in the insect groups depicted) and clear diagrams that adorn each page. It brings together information on many of Australia's highly characteristic and endemic endophytic insects in a context that emphasises their intriguing ecology



and peculiarities, and their values to humanity. Written for the non-specialist, the seven (unnumbered) chapters flow logically in linking central themes.

In her introduction, Dr Blanche emphasises the great variety of galls, and that each may be highly characteristic, with its form and host plant often diagnostic for the causative agent. Illustrations show several representatives, including the *Uromycladium* fungus gall on *Acacia*, which can be subsequently invaded by many kinds of insect, some of them specific to this habitat; some photographs depict galls opened to reveal their inhabitants. This chapter is wide-ranging and informative, but here (and later in the book) the cautionary comments on what we do *not* know pose many intriguing questions for investigation. The second chapter is a broad introduction to the variety of gall-inducing insects, emphasising the paucity of knowledge of many groups that include some notable Australian radiations of species. I found this account in places a little too abbreviated—comment on Hymenoptera, for example, does not mention many of the taxa that are used as examples later in the book—but the synopsis does generally set the scene well for the next two chapters on gall insect biology ('Remarkable adaptations', 'Enemies of gall-forming insects'). The intricacies of the various relationships are well considered, and it was a pleasure to see photographs of my favourite wasp parasitoid of gall-formers—the spectacular 'dart-tailed wasp' (*Cameronella*) that attacks *Apiomorpha* coccoids. The full array of such associates remains to be documented for almost all Australian gall communities.

The penultimate two chapters move to the impacts and values of gall-insects to people, as pests (such as the citrus gall wasp, *Bruchophagus fellis*) and biological control agents (such as the *Trichilogaster* wasps used to control pestiferous Australian acacias in South Africa). Other values include pollination, with the unique mutualisms of figs and fig wasps (Agaonidae) described clearly.

A final chapter, obligatory reading for field naturalists, shows how people can contribute meaningfully to enlarging knowledge of gall insects, through studying and rearing them. An innovative school project is described, as an example of community contribution, and the possibilities for parallels are endless.

The book concludes with a short pertinent 'further reading' list, a glossary and an index.

Dr Blanche has achieved a great deal in this short book; she writes enthusiastically and conveys complex information very clearly. It is also very well produced. I have no hesitation in recommending the book as a significant summary and introduction to the variety of gall insects in Australia, and of wide interest to naturalists of many persuasions.

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Thank you from the Editors

The Victorian Naturalist could not be published, and would not be successful without the enormous amount of time and effort given voluntarily by a large number of people who work behind the scenes.

As always we particularly thank our authors, who provide us with excellent material for publication.

One of the most important editorial tasks is to have papers refereed. The Editors would like to say 'thank you', therefore, to the following people who refereed manuscripts that were published during 2012:

Gary Backhouse
Melanie Birtchnell
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Mark Hutchinson
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Euan Ritchie
Don Sands
Bernadette Sinclair
Rob Wallis

The Victorian Naturalist publishes articles for a wide and varied audience. We have a team of dedicated proofreaders who help with the readability and expression of our articles. Our thanks in this regard go to:

Andrea Ballinger
Lucy Bastecky
Ken Bell
Leon Costermans
Arnis Dzedins
Ian Endersby
Maria Gibson
Ken Green
Pat Grey
Murray Haby
Jamie Harris
Virgil Hubregtse
Alison Jones
Michael McBain
Keith Marshall
Angus Martin
Geoffrey Paterson
Gary Presland
Simon Townsend
Rob Wallis
Alan Yen

Sincere thanks to our book reviewers for 2012 who provided interesting and insightful comments on a wide range of books:

Graeme Ambrose
Nick Clemann
Don Garden
Anne Morton
Tim New
Martin O'Brien
Gary Presland
Alex Ritchie
Rob Wallis

On the production side, thank you to:
Ken Bell, who prepares the annual index,
Printers, BPA Sands, especially Tom Markovski,

and

a special thankyou to Dorothy Mahler
for her administrative assistance over the past 13 years

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December 2012

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Phillips A and Watson R (1991) *Xanthorrhoea*: consequences of 'horticultural fashion'. *The Victorian Naturalist* **108**, 130-133.

Smith AB (1995) Flowering plants in north-eastern Victoria. (Unpublished PhD thesis, The University of Melbourne)

Wolf L and Chippendale GM (1981) The natural distribution of *Eucalyptus* in Australia. Australian National Parks and Wildlife Service, Special Publications No 6, Canberra.

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Reptiles and Amphibians – Cogger H (2000) *Reptiles and Amphibians of Australia*, 6th edn. (Reed Books: Chatswood, NSW)

Insects and Marine Creatures – ABRS: <http://www.environment.gov.au/biodiversity/abrs/online-resources/fauna/index.html>

Birds – Christidis L and Boles WE (2008) *Systematics and taxonomy of Australian birds*. (CSIRO: Collingwood, Victoria)

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